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PERFORMANCE EVALUATION OF THIN LAYER THERMOELECTRIC DEVICE.(U)

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PERFORMANCE EVALUATION OF THIN LAYER THERMOELECTRIC DEVICE

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This report evaluates the performance characteristics of a thin layer thermoelectric device, developed for use in special cooling applications. Test results, conclusions, and recommendations are included.

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PREFACE

This is a final report relating to a Naval Avionics Facility, Indianapolis (NAFI), evaluation of a thin layer thermoelectric device, developed under NAVAIR contract N00019-76-C-0258 by Ohio Semitronics, Inc. (OSI), Columbus, Ohio, as reported by J. W. Harpster and J. A. Sanborn in "Integrated Thermoelectric Devices; Manufacturing Methods Study." These tests were performed at the request of NAVAIR (AIR-52022F).

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ABSTRACT

This report evaluates the performance characteristics of a thin layer thermoelectric device, developed for use in special cooling applications. Test results, conclusions, and recommendations are included.

TABLE OF CONTENTS

APPENDICES

ILLUSTRATIONS AND TABLES

I. CONCLUSIONS

1. The target objective of achieving an average temperature drop of 30°C with zero heat load was not realized during the NAFI verification testing. The actual average measured temperature drop for a sample size of seven OSI thermoelectric devices (TED) was 28°C, with several of the devices realizing thermal differentials in excess of the targeted 30°C differential. The OSI report states that their tests indicate an average change in temperature (ΔT) of 27°C.

2. The large thermoelectric device (0.375 inch by 0.375 inch) demonstrated a heat pumping capability slightly in excess of one watt, with a 20°C drop in temperature from ambient.

3. The small TED (0.25 inch by 0.25 inch) demonstrated a heat pumping capability of approximately one-quarter watt with a 20°C drop in temperature from ambient.

II. RECOMMENDATIONS

1. Process refinements should be pursued to eliminate the broad variations in the different TED temperature drops.

2. If sufficient applications are defined, the thermoelectric device technology appears to be sufficiently mature to permit industry manufacture and qualification of the devices.

3. Development of suitable specifications for qualification and acquisition of TEDs should be given attention by AIR-520 if suitable applications are defined.

III. INTRODUCTION

For many years it has been recognized that there are many electronic equipments that require several, but not all, electronic components to operate at reduced temperatures in order to realize necessary operating performance requirements. In almost all modern equipments, it is necessary to air condition (forced air or forced cooled air) the entire assembled system/subsystem; a very inefficient and costly means to meet critical operational requirements. Realizing the need for localized cooling of electrical components, especially in critical areas of Naval avionics where cooling is both very necessary and costly, the Naval Air Systems Command (NAVAIR) contracted Ohio Semitronics, Inc. (OSI), Columbus, Ohio, to determine manufacturing methods for obtaining adequate compatibility between components for a thin layer thermoelectric device for cooling semiconductor devices. This work was performed under NAVAIR contract N00019-76-C-0258. Upon completion of the contract, NAFI was requested to independently verify the OSI results. This report documents the findings of that brief study.

OSI designed and fabricated two sizes of thermoelectric devices; the larger unit contains a semiconductor element that is approximately 0.375 inches square, while the smaller device is approximately 0.25 inches square. These devices are shown in Figures 1, 2, and 3 for reference. The basic structure of these TEDs is deposited N and P-type bismuth telluride (Bi_2Te_3). Nickel-plated copper strips, which have been attached/plated on alumina (Al_2O_3) substrates, are soldered to the semiconductor element tops to form a sandwich device, as shown in Figure 3. The small side of the sandwiched device can then be attached to the element to be cooled while the larger side serves as the heat radiator.

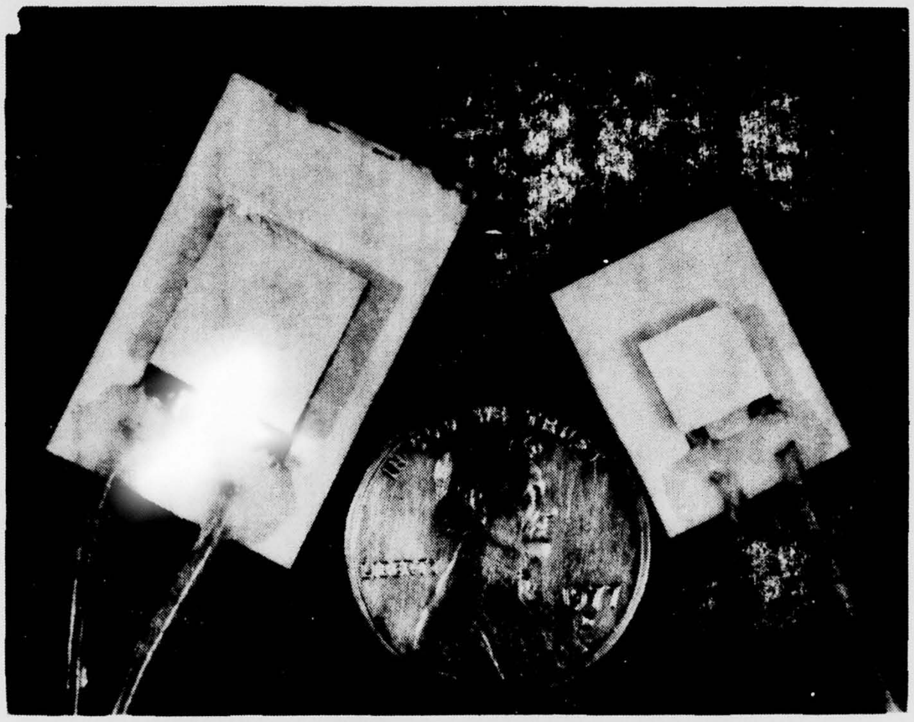

FIGURE 1. Two Types of OSI Thermoelectric Devices

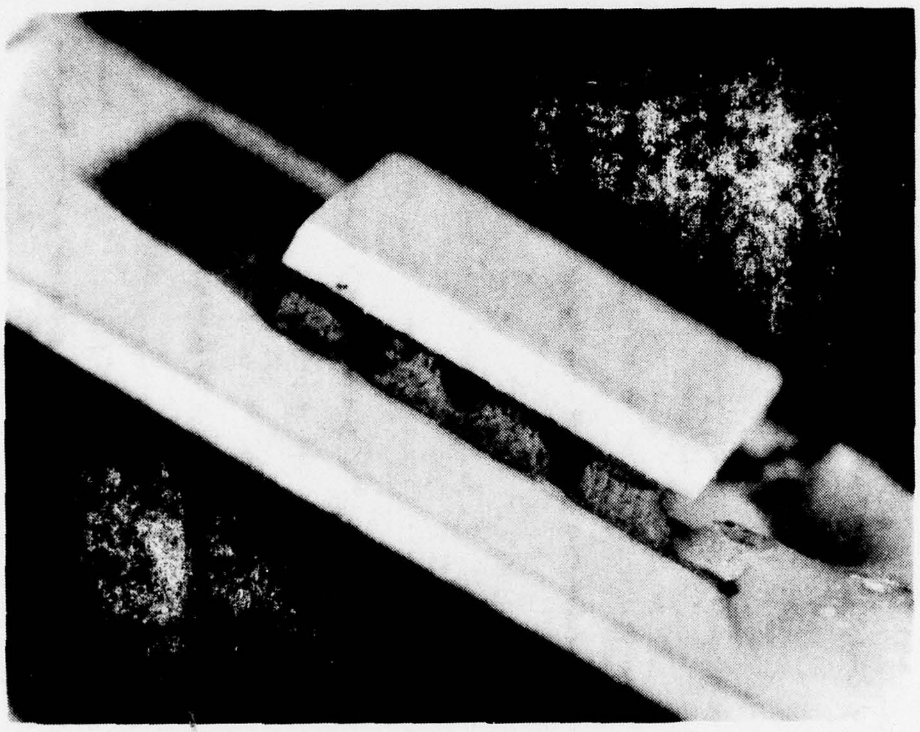

FIGURE 2. Side View of TED

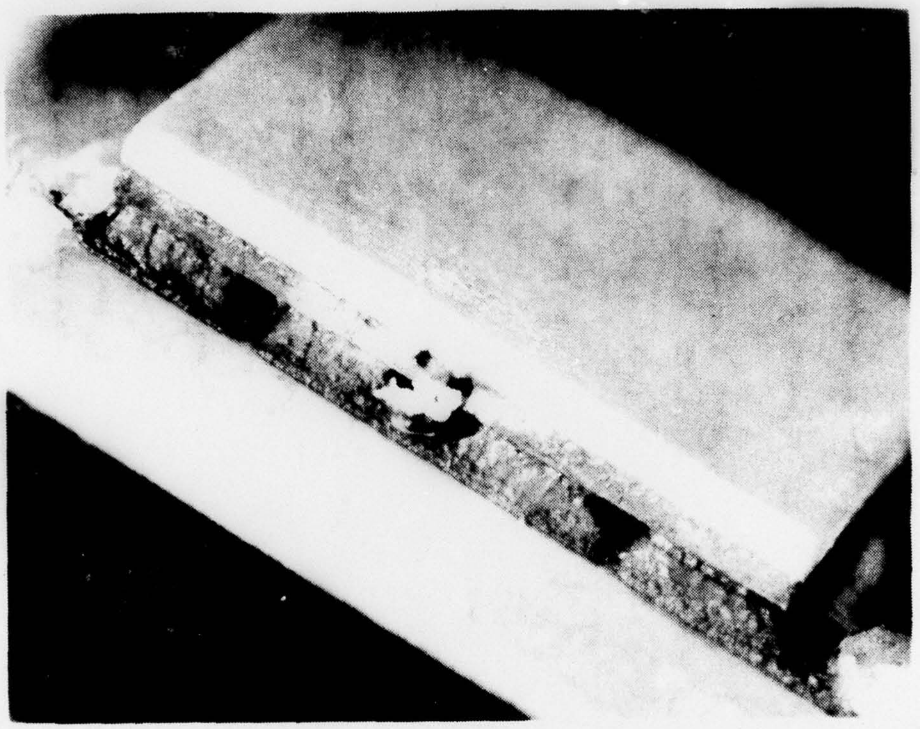

FIGURE 3. Close-Up View of TED

IV. TEST RESULTS

The summarized results of the evaluation of the thin layer thermoelectric devices are:

1. The average temperature drop with no heat load on the TEDs was 28°C, slightly below the objective of 30°C. Test data for the seven devices are summarized in Table 1. Raw data are presented in graphical form in Figures 4 and 5.

2. There were significant deviations in individual device temperature drop, ranging from 23°C to 32°C for the seven devices tested.

3. The larger size TED demonstrated a capability of pumping 1 to 1.25 watts at a ΔT of 20°C (see Figure 6).

4. The smaller size TED demonstrated a capability of pumping 0.2 to 0.3 watts at a ΔT of 20°C (see Figure 7).

TABLE 1. TEST DATA FOR THERMOELECTRIC DEVICES

TED ID NUMBER	SIZE	MAXIMUM ΔT°C	% DEVIATION FROM MEAN
5	.25" x .25"	26°C	-6.2%
6		27°C	-2.6%
7		32°C	15.5%
8		23°C	-17%
10	.375" x .375"	31°C	12%
12		27°C	-2.6%
13		28°C	1.1%

NOTE: System measurement accuracy was ±1°C.

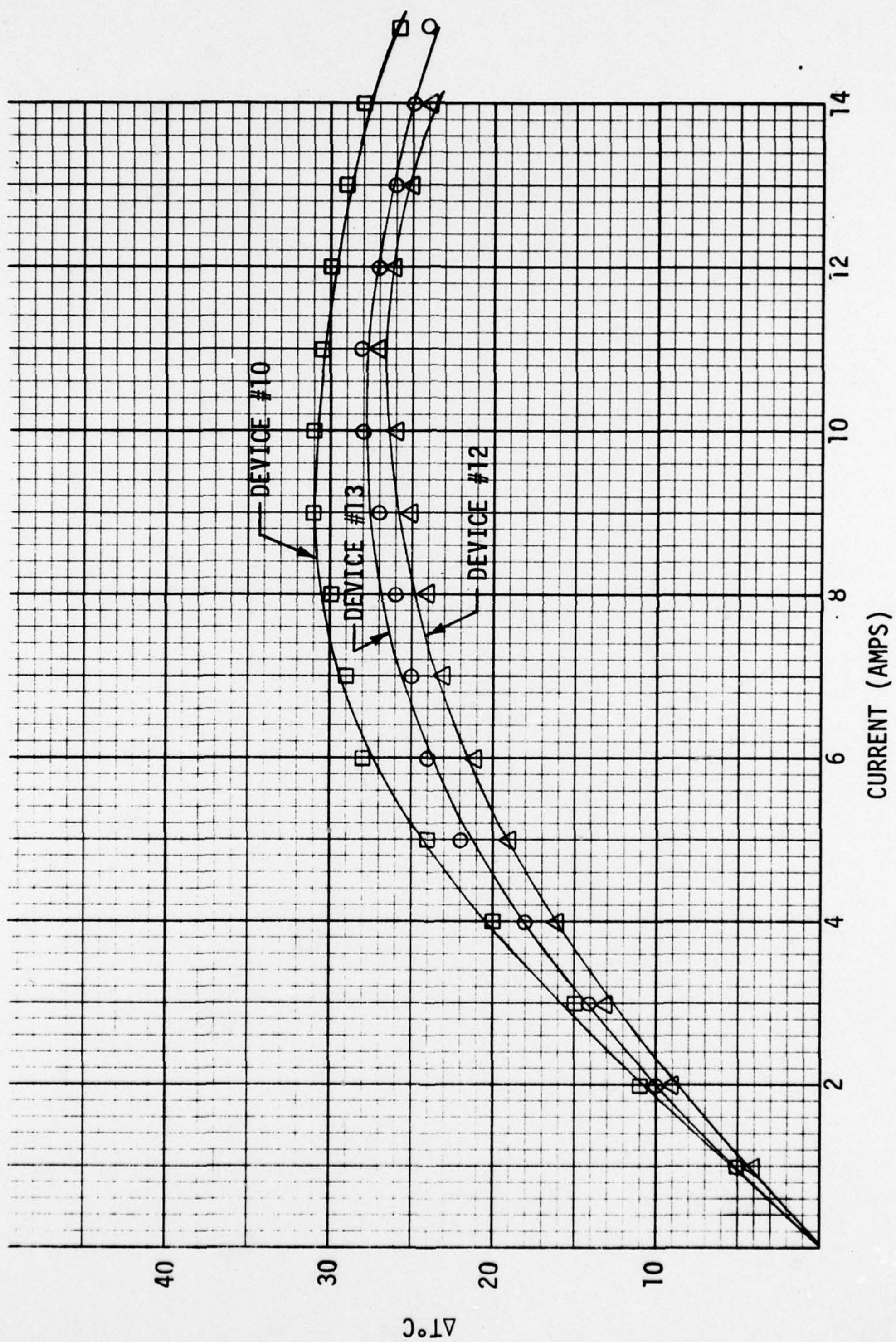

FIGURE 4. MAXIMUM TEMPERATURE DROP VS. CURRENT (LARGE TED)

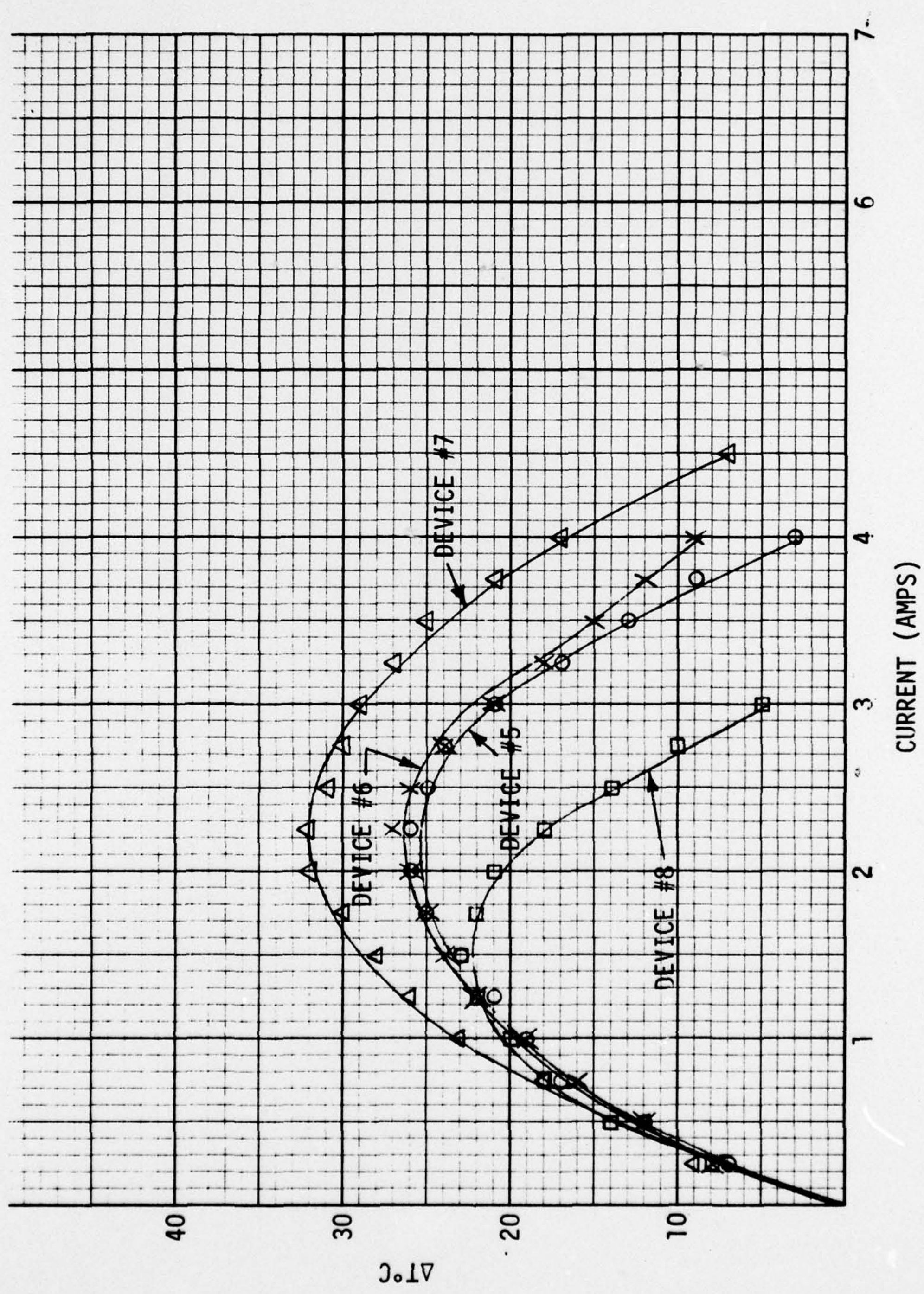

FIGURE 5. MAXIMUM TEMPERATURE DROP VS. CURRENT (SMALL TED)

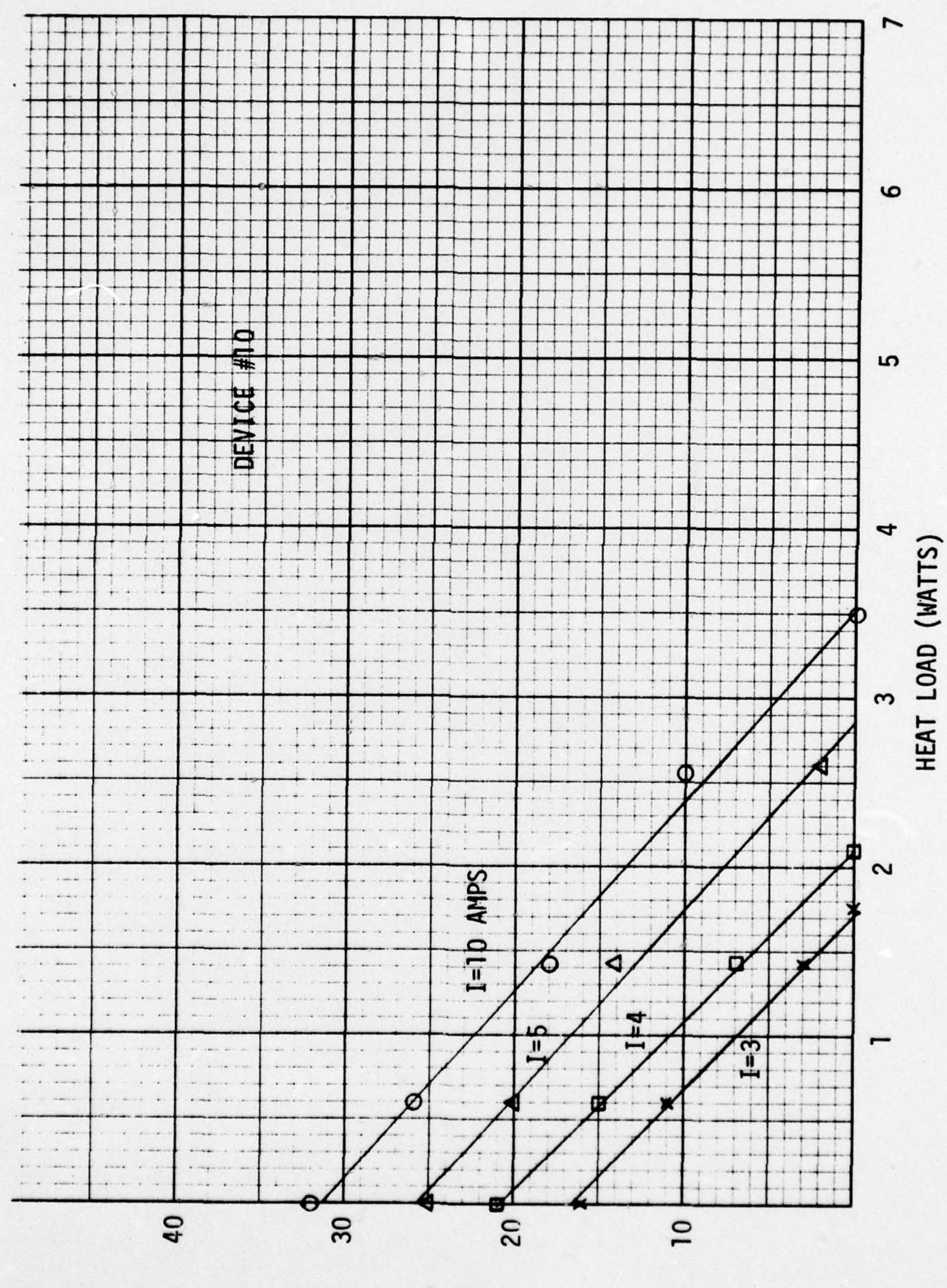

FIGURE 6. CHANGE IN TEMPERATURE VS. HEAT LOAD (LARGE TED)

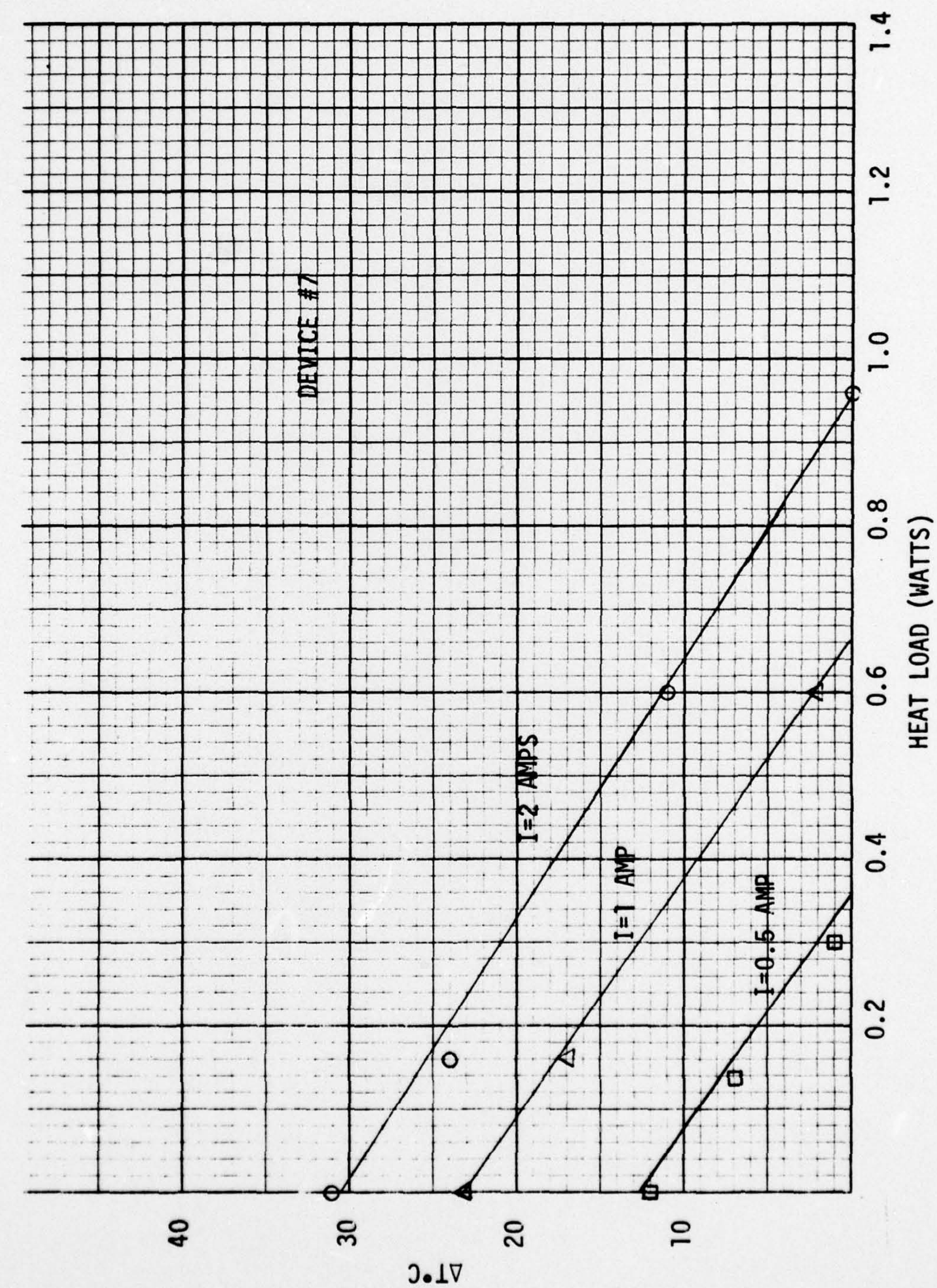

FIGURE 7. CHANGE IN TEMPERATURE VS. HEAT LOAD (SMALL TED)

V. TEST METHOD

A. Fixtures

Tests on the thermoelectric devices were carried out with the apparatus shown in Figure 8. The TED was placed inside a 9-inch glass bell jar with a rubber vacuum seal at its base. On the 1-foot x 1-foot x 1-inch aluminum base plate, there were connections to the vacuum pump and to a release valve for the vacuum. Also on the base plate were connections for a vacuum gage. The electrical connections were made through the vacuum seal by an electrical feedthrough on the base plate.

The TED under evaluation, with an attached thermocouple on the hot side, was placed on the base plate with Dow Corning 340 heat transfer compound between the TED and the base plate. A copper sheet, 1/4-inch x 1/4-inch x 0.005 inch, with an iron-constantan thermocouple attached, was placed on top of the TED with heat transfer compound in between. A small thick film resistor (approximately 250 ohms) providing the working heat load was placed on top of the copper sheet with heat transfer compound in between. A 1/8-inch x 1/8-inch x 1/2-inch Teflon thermoisolator block was then inserted between a hold-down screw and resistor. This assembly was held in position by tightening the hold-down screw assembly.

The cross-sections of the wires feeding the current to the resistor and the thermocouple wires were selected so as to make the heat flux along their lengths negligible, so that the entire heat generated by the resistor was transferred to the cold junction of the TED.

An electrical feedthrough provided connections for the TED, resistor, and thermocouple outputs.

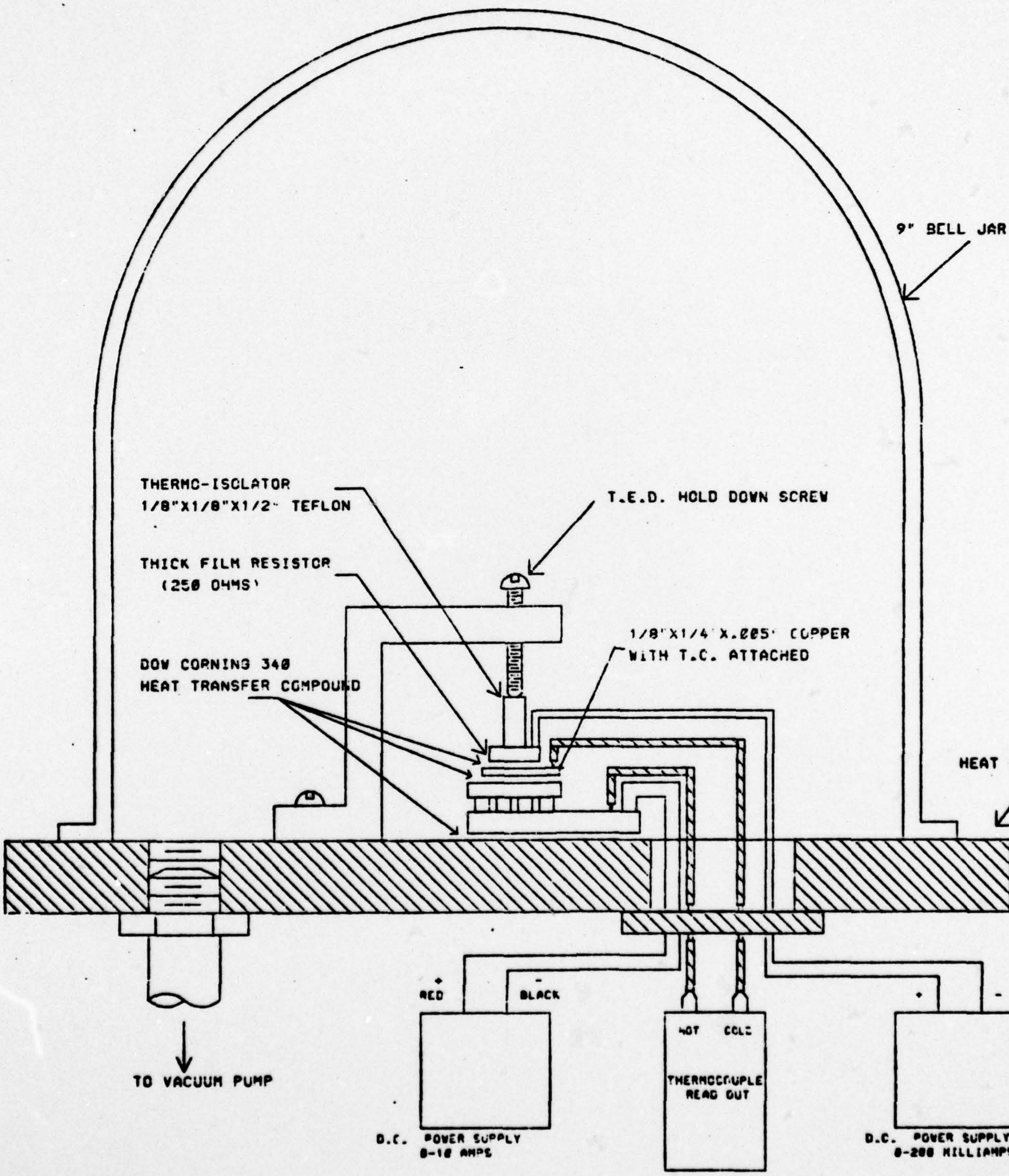

FIGURE 8. THERMOELECTRIC DEVICE TEST APPARATUS

B. Test Procedure

1. The bell jar was evacuated to a pressure of 100 micrometers or less, a procedure requiring approximately one hour.

2. A set current was applied to the TED.

3. The system was allowed to come to equilibrium (two to three minutes) and measurements were taken of the temperature drop between the junctions of the TED, with the temperature of the hot side remaining constant (approximately 25°C).

4. The set current in the TED was increased by 0.25 ampere increments in the smaller device and by 1 ampere increments in the larger device.

5. Steps 3 and 4 were repeated until the maximum temperature drop for the device had been reached.

This data of ΔT versus current into the TED of zero heat load is shown in Figures 4 and 5 for the seven devices.

The second set of data was taken from only two devices, each of which had exhibited the best characteristics of its size group.

6. Steps 1 and 2 were repeated.

7. A set current was applied to the thick film resistor to give a heat load to the TED.

8. After two or three minutes, when the system had come to equilibrium, measurements were taken of the temperature drop between the junction

of the TED and the voltage across the resistor to find the heat load (in watts) being pumped by the TED.

9. The set current in the resistor was increased.

10. Steps 8 and 9 were repeated until the temperature drop between the junctions of the TED was close to zero degrees.

11. The set current in the TED was changed.

12. Steps 7 through 10 were repeated.

13. Steps 11 and 12 were repeated.

This data of ΔT as a function of heat load at constant values of current to the TED is shown in Figures 6 and 7.

APPENDIX A

LIST OF TEST EQUIPMENT

Welch Scientific Company
Duo-Seal Vacuum Pump, Model 1403, Serial No. 9644

Hewlett-Packard
Harrison 6206B DC Power Supply, NAFI 6245

Keithley Instruments
610B Electrometer, NAFI 17164

Kepco
3619M DC Power Supply, NAF 15953

Veeco
Vacuum Gauge, Type RG-3A, NAFI 620298

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